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COMPARISON OF RULES FOR CALCULATING THE STRENGTH OF STEAM BOILERS.

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1. THE object of this paper is to attract the attention of engineers to variations in the rules now in use for determining the strength of the different parts which make up a steam boiler, with the hope that it may elicit a full discussion of the question whether or not it is desirable to prepare a set of standard rules for strength.

Universal standards, based on scientific methods coupled with experiment and experience, are now being adopted with advantage by both engineering and commercial interests.

Engineers have accumulated sufficient experience to predict with accuracy results that can be expected. Such predictions as to strength of boilers are foretold by calculations founded on analytical science, with constants supplied by experiment. Engineering literature is rich with records of these experiments, and the results obtained are in close enough accord for all practical purposes.

The author will not attempt a complete analysis of the rules in force, as most engineers are fully aware of the discrepancies, but will simply compare a few rules for the sake of illustration.†

DATA ASSUMED.

Type of boiler	Scotch.
Mean diameter	12 feet 7 inches = 151 inches.
Working steam pressure	130 pounds above atmosphere.
Material	Steel.
" tensile strength	60,000 pounds.
Thickness of shell	$\frac{7}{8}$ inch.

* Presented at the New York meeting (December, 1900) of the American Society of Mechanical Engineers, and forming part of Volume XXII. of the *Transactions*.

† A lengthy comparison was made by Mr. N. Foley—see "International Engineering Congress," Division of Marine and Naval Engineering, Vol. II., 1894.

Joints, longitudinal.....Double butt straps of equal width, double riveted.
" transverse .....Lapped, double riveted.
Rivets, material.....Steel.
" diameter .....1 inch.
" pitch .....4 inches.
Flat heads, steam space, thickness .....$\frac{3}{4}$ inch.
Long stays, steel, spacing.....15 inches.
" fastening.....Double nuts, thinnest washer allowed.
Stay-bolts, spacing .....8½ inches.
" fastening .....Screwed, single nuts.

2. From the above data the working pressure allowed on the shell in pounds per square inch would be as given in Table I.

TABLE I.

I. United States Board of Supervising Inspectors of Steam Vessels....	139.0
II. Lloyd's Rules.....	116.8
III. Board of Trade	111.0
IV. British Corporation	118.6
V. Bureau Veritas.....	110.8

The difference is 28.2 pounds, or over 25 per cent.

The first rule makes no allowance for workmanship or proportions of joint. The other four rules include the percentage of strength of joint, while the third rule has a sliding scale for workmanship, shop methods, and general design.

3. The working pressure allowed on the flat heads in the steam space, when not exposed to the hot gases, and when the stays are fitted with double nuts and a washer on the outside, riveted to head and of minimum thickness mentioned in the rule, would be as given in Table II.

TABLE II.

I. United States Board of Supervising Inspectors of Steam Vessels....	184.3
II. Lloyd's Rules.....	128.0
III. Board of Trade	144.3
IV. British Corporation	127.9
V. Bureau Veritas	130.9

The difference is 56.4 pounds, or over 44 per cent.

The rules are not alike as to the size and thickness of the minimum riveted washer mentioned, and consequently the variation is largely due to the value of the constant employed.

4. Taking the data as assumed, and making the calculations

for a working pressure of 130 pounds, the results for the parts specified would be as given in Table III.

TABLE III.

Part of Boiler.	I. United States S. I. S. V.	II. Lloyd's Rules.	III. Board of Trade.	IV. British Corporation.	V. Bureau Veritas.
Thickness of shell, inches	0.8229	0.9594	1.0239	0.9532	1.0201
Nearest 32d	$\frac{27}{32}$	$\frac{31}{32}$	$1\frac{1}{32}$	$\frac{31}{32}$	$1\frac{1}{32}$
Thickness of flat surfaces, screw stay-bolts, 8½-inch centres, fitted with nuts, inches	0.5531	0.5531	0.5232	0.5338	0.4842
Nearest 32d	$\frac{18}{32}$	$\frac{18}{32}$*	$\frac{17}{32}$	$\frac{17}{32}$	$\frac{16}{32}$
Area of long steel stays, square inches	3.656	3.656	3.250	3.262	3.259
Diameter—nearest 16th	$2\frac{3}{16}$	$2\frac{3}{16}$	$2\frac{1}{16}$	$2\frac{1}{16}$	$2\frac{1}{16}$

5. Certain essential details are not provided for by some of the regulations, but are in others. Some inflict penalties for poor workmanship and defective design, while others allow the same pressure on the best as well as the poorest boiler when made from the same material. Corrosion is provided for by the addition of a fixed thickness to the calculated part under some regulations, while in others it is included only in the general factor of safety. This factor of safety necessarily differs in all the regulations.

The author is not aware that there have been any more failures under the regulations giving the minimum thickness than under those of the maximum. If the minimum is ample, why use the maximum? If, under the high pressures now maintained, the maximum is needed for safety, is it not opportune to increase the minimum? If the minimum is sufficient, then from Table III. it will be apparent that under any one regulation the boiler is not of equal strength throughout its parts, nor is there the same allowance for the more rapid corrosion of certain parts over others. Thus, if the shell thickness under Regulation I. be correct, it is not necessary to have it as heavy as under Regulations III. and V., while the staying of Regulations III. and V. are lighter than in Regulation I.

6. The author does not desire to present this paper as an

* $\frac{17}{32}$ is too thin, but for $\frac{18}{32}$ pressure could be 151 pounds, or nearly 17 per cent. more than required.

argument either for or against the idea of appointing a committee to consider and draft a set of regulations, but does so with the hope that the members will freely express their opinions on the question. If a committee be appointed, the author would suggest that the committee contain as members representatives of the various recognized regulations, so that the rules proposed may have a universal standing.

APPENDIX.

Below is appended a short statement of the regulations referred to above:

Meaning of Letters.

S denotes tensile strength in pounds per square inch.
S_1 " " " " tons " " "
t " thickness of part in inches.
T " " " parts in sixteenths of an inch.
D " mean diameter of shell in inches.
B " least percentage of strength of joint.
C " constant.
p " pitch of stays in inches.
a " spacing of rows of stays in inches.
W " working pressure in pounds per square inch.

Cylindrical Shell.

United States Board of Supervising Inspectors of Steam Vessels:

$$\frac{1 \times S \times 2 \times t}{6 \times D} = \text{working pressure, to which add 20 per cent.}$$

for double riveting.

Lloyd's Rule:

$$\frac{C \times (T-2) \times B}{D} = \text{working pressure.}$$

Board of Trade:

$$\frac{(S \times B) \times 2 \times t}{D \times C} = \text{working pressure.}$$

NOTE.—In this rule C is a minimum factor of safety, with additions according to circumstances.

British Corporation:

$$\frac{C \times (T-1) \times B}{D} = \text{working pressure.}$$

Bureau Veritas:

Calculates rupture through "Plate," "Rivets," "Plate and Rivets," "Butt Straps," and "Butt Straps and Rivets." Uses the minimum pressure so found. Formulæ allow 0.04 inch in thickness for corrosion.

Flat Surfaces.

United States Board of Supervising Inspectors of Steam Vessels:

$$\frac{C \times T^2}{p^2} = \text{working pressure.}$$

Lloyd's Rules:

$$\frac{C \times T^2}{p^2} = \text{working pressure.}$$

Board of Trade:

$$\frac{C \times (T-1)^2}{(a \times p) - 6} = \text{working pressure.}$$

British Corporation:

$$\frac{C \times (T-1)^2}{a \times p} = \text{working pressure.}$$

Bureau Veritas:

$$\frac{(T-1)^2 \times S_1}{(a^2 + p^2) \times C} = \text{working pressure.}$$

Steel Stays.

United States Board of Supervising Inspectors of Steam Vessels:

For stays not exceeding $2\frac{1}{2}$ inches effective diameter, 8,000 pounds per square inch of section. Stays exceeding $2\frac{1}{2}$ inches, 9,000 pounds.

Lloyd's Rules:

For stays not exceeding $1\frac{1}{2}$ inches effective diameter, 8,000 pounds per square inch of section. Stays exceeding $1\frac{1}{2}$ inches, 9,000 pounds.

Board of Trade:

For stays, when material has tensile strength from 27 to 32 tons, 9,000 pounds per square inch.

British Corporation:

$$\sqrt{\frac{a \times p \times W}{8{,}000}} + \tfrac{1}{8} = \text{effective diameter, inches.}$$

Bureau Veritas:

$$\sqrt{\frac{a \times p \times W}{300 \times S_1}} + \tfrac{1}{8} = \text{effective diameter, inches.}$$

DISCUSSION.

Mr. R. S. Hale.—Mr. Parsons's paper is a very interesting one, in bringing out the different results obtained when using various standard rules for boiler designs. The practice of the Mutual Boiler Insurance Company, for which I am consulting engineer, may not be absolutely correct, and may not be the best, but a statement of our practice may show the difficulty in establishing any set of standard rules.

Taking up first the question of the cylindrical shell, I will refer to the horizontal return tubular boiler, as by far the great majority of boilers which come under our inspection are of this type.

The factors covering the pressures to be allowed on these boilers are thickness of the plate, the strength of the metal, the efficiency of the joint, and what may be called the moral factors, such as the design of the boiler, the workmanship during construction, and the use to which the boiler is put. In regard to the efficiency of the joint, we always compute this from the strength of the metal and of the rivets. We do not, however, often find it necessary in new boilers with butt-strapped joints to consider particularly the strength of the rivets in shear, since, if the joint is properly designed for a tight joint, the rivets are usually much stronger than the plate. On lap joints this is not necessarily the case, but lap-joint boilers are now very seldom put in by our members, except for heating purposes, where the pressure carried does not exceed 15 pounds per square inch, and where the margin of strength is very high.

In regard to the tensile strength of the metal, it is our custom to specify that the tests of coupons in the sheets shall not be less than a certain amount, usually 55,000 pounds per square inch, nor more than a certain amount, usually 65,000 pounds per square inch. We also specify that the elongation in 8 inches shall not be less than a given amount, usually 25 to 30 per cent.,

and that the phosphorus and sulphur shall not exceed certain limits, usually .035 per cent. These requirements represent the usual mild steel specifications. So long as the metal comes up to the specifications called for, we pay no attention to the exact tensile strength found on the test, but design for the moderate stress in the weakest point in the riveted joint of 12,000 pounds per square inch. This corresponds to a factor of safety of 5 if the strength of the metal is taken as 60,000 pounds per square inch, or to a factor of about 4½ if the tensile strength is taken at 55,000 pounds per square inch.

We make no allowance for future corrosion in the design of the boilers, except in so far as we use a lower unit stress in designing than we consider safe, so that even with some slight corrosion the boiler can still be run at the pressure for which it is designed.

The above data determine the pressure on new boilers built to our specifications, and we expect that such boilers will be able to carry their pressure for many years without any necessity to reduce it. Of course, if a boiler shows signs of distress or severe corrosion, it might be necessary to cut down the pressure, but we consider that a boiler with metal of the above quality and with butt-strapped joints is safe, even if the metal is stressed considerably above 12,000 pounds per square inch, so that there is a considerable margin for corrosion or other troubles.

In the case of a boiler which is submitted to us for inspection and insurance we adopt the same rules as above given, but in this case we cannot give our members any assurance that they will be able to carry a pressure corresponding to a unit stress of 12,000 pounds per square inch on their boilers for any length of time. However, on boilers with the butt-strapped joint, where we have reasonable grounds to believe that the metal is of good quality, there is but slight probability that we should find it necessary to cut down the pressure, and we even allow higher pressures to be carried after giving notice that such higher pressures may be only temporary.

On old boilers, however, where the joints are lap joints, and most especially where these joints are exposed to the fire, we never allow a greater pressure than that corresponding to a unit stress of 12,000 pounds per square inch (factor of safety of 5). It is true that in occasional cases, when cutting down the pressure would involve shutting down the whole steam plant, we sometimes allow a higher pressure for a few months until new boilers can be procured.

In special cases, such as very old boilers showing signs of distress, we do not even allow as high a pressure as this.

It will thus be seen that our rule corresponds to the English Board of Trade rule, except that we take a fixed value for the strength of metal, and that our C is an average factor of safety for which we make allowances in the cases of boilers which are especially well designed and made, and additions only in the case of old boilers which show signs of distress.

Of course the rules stated above apply only to the mild steel which is now universally used for boilers. We were recently asked to insure some boilers which were to be built of nickel steel. We went into the subject as thoroughly as we could at the time with the literature and tests available, and finally told the parties who wished to build these boilers that we were prepared to allow a unit stress considerably above the 12,000 pounds per square inch which we allowed on mild steel, and that the excess would depend largely on the quality of nickel steel which they proposed to use, and the specifications to which it was made. The boilers were, in the end, not built, so that the question was not considered further. We also have a number of old iron boilers under ur charge on which we usually allow 8,000 to 10,000 pounds stress on the metal. These boilers, however, are almost all made with lap seams, and we are encouraging our members to replace them as fast as possible with a safer type.

All the above discussion refers to horizontal return tubular boilers. We also have under our charge a large number of vertical tubular boilers, both of the ordinary type and of the Manning type. On these we adopt the same general rules with the exception that our specifications as to the quality of metal are not quite as stiff, since the metal of the outside shells is not exposed to the heat of the fire, and we also allow a slightly greater stress on the metal of the outside shells, going up as high as 13,333 pounds per square inch, corresponding to a factor of safety of $4\frac{1}{2}$, if the tensile strength be taken as 60,000. On old boilers of this type with lap seam joints we are averse to allowing more than 12,000 pounds per square inch stress in the metal. On new boilers with butt strap joints and metal of good quantity we should not be afraid to allow 15,000 pounds per square inch, corresponding to a factor of safety of 4, provided our members understood that this pressure might be reduced at any time.

In regard to stayed surfaces we have two cases to consider.

First, in horizontal tubular boilers. In these we stay the heads preferably with through and through rods of large size, say, of about 2 inches diameter, with channel bars or angle bars riveted to the heads to stiffen them. On these rods we allow a stress of 9,000 pounds per square inch.

On the fire box of vertical tubular boilers we have usually adopted the United States rule. This gives the highest pressure of any of the rules in common use, but even in large boilers with the fire box six or seven feet in diameter, the fire box is, to a certain extent, self-sustaining, so that we have thought the rule gave ample margin, particularly as we know of very few cases of failure of boilers at this point.

On small vertical tubular boilers, of which we have quite a number under inspection, even the United States rule would require a very much larger number of stays than is found practically necessary. We have had occasion to design but very few small boilers of this type, as most of the boilers under our inspection were already at work when brought to us for approval or to determine a pressure. In the latter cases we have computed the permissible pressure by the United States rule, and also the permissible pressure considering the fire box as a collapsible flue. If the sum of these two pressures, *i.e.*, the pressure which the fire box will carry as a collapsible flue, added to the stiffening effect of the stays, was greater than the pressure which the user of the boilers desired to carry, we have considered ourselves safe in allowing that pressure, and have never had any difficulty.

As will be seen from the above statement, there would be great difficulty in adopting any rules which could take into account all the different factors of different qualities of metal, different design of joints, different grades of workmanship, different allowances for corrosion, and differing services for which the boilers are to be used. At the same time full discussion of all these questions would be of great value to designers and insurers of boilers.

Mr. F. A. Scheffler.—This paper is one of the most important papers ever presented to the Society. The writer has had considerable experience in designing and constructing boilers of various kinds, but never before have I fully realized that there is such a discrepancy between the "rules" used by various important supposed-to-be authorities as is briefly and tersely set forth in Mr. Parsons's paper.

Personally, I believe that the best rule as to strength of shells

is the one used by the Board of Trade, as the strength of joint is taken into consideration, which, in my opinion, is the only proper way to obtain the true strength of the shell. It is surprising that, with all the brains which our government has at its command, no one at Washington has had the sense to correct or revise the loose rule now in existence for determining the strength of shells.

This rule is so old that you can almost see the gray hairs on it. It is wrong in more ways than one, but I call attention to the fact that 20 per cent. is not always the increase in strength of the joint by double riveting. One can design a joint in double riveting which will only increase the strength 10 per cent., or which will increase it 30 per cent., if the single riveted joint with which it is compared is a bad one. Query: Does the department allow 30 per cent. additional pressure for a triple riveted joint?

On the other hand, the Board of Trade's rule for flat surfaces is not so conservative, and some of the others are better.

I am heartily in favor of appointing a committee to endeavor to adopt some standard which will be used all over the world, and trust this matter will meet with the attention it deserves in the hands of our Society.

Mr. Edward P. Thompson.—Common sense is a rule which has been referred to. Yet that is a most indefinite term. I have become interested lately in the strength of steam boilers, and find there is no common sense about a certain feature, so far as I can see. Not long ago I was called upon to make an examination in connection with a blow-out of a locomotive. The locomotive was going down grade, and some unusual sound was heard. The engineer saw the fireman blown off the locomotive and rolling down the bank. After being picked up he was found to have been scalded, and that is the way he met his death, rather than by the tumble he had. He was able to testify, however, a little while afterward, before he died, and he merely thought it was a blow-out of a tube, and in that case, of course, it would be looked upon as an ordinary occurrence and something which could not well have been prevented. But in this particular instance it could have been prevented, and if this practice of plugging boilers is kept up there will be plenty of accidents of that kind. There have probably been a great many accidents which we have never heard about—cases where the party injured does not make any complaint. This was the nature of the accident: The foreman had ordered some tubes at the lower part of the boiler to be removed,

and "common sense" in this case was merely a name for a certain practice with which he had become acquainted, and therefore it was common sense to him. Others had done it, and therefore he could do it, and that is what his common sense was. He plugged up the twelve holes where the six tubes had been taken out. If you take out half a dozen tubes which act as ties to hold the heads together, the boiler will be that much weaker. That is mathematical reasoning. I believe in basing rules upon reason rather than upon common sense, because people have different ideas about common sense. He plugged up the holes. It was difficult to determine whether these holes were plugged up by threading the plugs or by merely driving them in. One witness held they were merely driven in. Another held that they were threaded. But it is quite immaterial, because a plug can be driven out when a tube could not be blown or burst. When the plug is in instead of the tube, you not only have the boiler weakened so as to allow the blowing out of the head, but the pressure upon the plug will be greater and more apt to produce the accident than if the tube is there, because the pressure can act longitudinally upon full end surface of the plug. Say the plug is 6 to 7 inches square in area, as it could easily be—perhaps about 6 square inches; multiply that by the pressure that they had—70 pounds—you will see there is a great deal of pressure upon that plug to blow it out. The only reason that somebody was injured in this case was that the man happened to open the door of the fire box, and happened to be standing in the way of the plug when it was driven out. But how many know how many plugs have been driven out, and people injured for life? So it would seem as if it were a matter of almost sufficient importance to have legislative action. But why should a body of intelligent engineers be forced to adopt a simple rule forbidding that plugs shall be employed where tubes have been removed for cleaning or for any other purpose?

Prof. H. W. Spangler.—It would seem to me that this question is largely a question of insurance. I have found in a number of cases where I have had boilers under my charge that the rules of a certain insurance company would not allow the boiler to be insured under that company with the dimensions which the boiler had and with the pressure which is to be carried. I have found that the insurance companies were always very amenable to reason, however, and that their rules would be modified if there

was good reason for doing it. As far as the rules given in Mr. Parsons's paper are concerned, they are practically, as far as foreign work is concerned, the rules of the insurance companies. As far as the United States rules are concerned, they are those rules which must be followed by vessels which are to be used in the navigable waters of the United States. If you are going to insure in a particular company, you want to build what that particular company is willing to insure after it is built. If you are willing to insure yourself, it seems to me you should design as you know is right, if you do know. I am satisfied that the rules of the United States supervising inspectors are far from being the best rules for the building of boilers which can be devised; but those of us who have had to deal with the foreign insurance companies, and have kept track of their rules for years, know that those rules are constantly being modified by their experience; and their experience, to my mind, is that common sense to which one of the speakers referred to to-day. Therefore, if one wants to insure his boilers, it seems to me it is nothing more than sensible that he should build his boilers as insurance companies call for. If those rules are not right, there is not much difficulty, if you get at the engineering side of the insurance company, in convincing them that the boiler you propose to build or to buy will do its work quite as satisfactorily as the boilers which they say they will insure. I have found there is very little difficulty in the handling of properly built boilers, although they may not be built exactly as the rules call for.

Mr. William Kent.—There was a long paper on this subject presented at the Engineering Congress in Chicago, in 1893, by Mr. Nelson Foley. Those who are interested in this subject ought to see that paper, as the author suggests in his note.

In regard to the United States rules, I think they have been condemned by every authority who has ever written on the subject. They are known to be less safe than any other rules, and the foreign rules, the Board of Trade, Lloyds, the Bureau Veritas, and others, are, as Professor Spangler says, being constantly modified by experience, while the United States rules are not modified by experience or anything else. They have been condemned by writers for the last 25 years, and they remain in the same old fossilized condition in which they always have been, with the single exception known to me, that a few years ago the Board of Supervising Inspectors did discover, 20 years after

other people had discovered it, that the neck form of test piece was not a good one for steel. I believe the rules still allow that neck form for iron. Years ago it was not good for either iron or steel, and the United States Board of Supervising Inspectors only four or five years ago did find out that it was not good for steel.

I am sorry that Mr. Parsons has this sentence in his paper: "The author is not aware that there have been any more failures under the regulations giving the minimum thickness than under those of the maximum." Mr. Parsons is enough of a lawyer to know that negative testimony is not good testimony. The fact that he did not see a man kill another is no proof that the man did not kill the other. But on the other hand the experience of the insurance companies of this country and the experience of foreign countries is that boilers ought to be built about as these foreign rules lay down. And they do not differ so much among themselves. For instance, the working pressure allowed on the flat heads, when not exposed to the hot gases, and when the stays are fitted with double nuts and a washer, etc., is 127, the British Corporation, and 144, Board of Trade, the two extremes, while the United States rules give 184 pounds. The working pressure allowed on the shell in pounds per square inch varies from 110 to 118 according to the foreign rules, while the United States rule gives 139 pounds. So the United States rule is the only one which is very far away. I think, if we want to build boilers, if we build them according to foreign rules or according to the rules of the American Insurance Companies, they will be all right.

I wish to put on the board a formula which I published years ago, and which I think a pretty good one for strength of shell of the boiler: Working pressure equals 14,000 times the thickness in inches, divided by the diameter in inches, $W = 14{,}000\ t \div d$. That, you see, is independent of the actual tensile strength of the steel. It is based on the supposition that the factor of safety of 5 is correct for 50,000-pound steel; a factor of 6 for 60,000, and a factor of 7 for 70,000. That is to handicap the higher carbon steel. As every one who knows anything about the manufacture of fire boxes knows, the very best steel you can get is the softest. So to prevent men putting in high carbon steel we handicap it by giving a higher factor of safety. It is also based on a rivet seam factor of 0.70, which will do for a very well-designed lap joint. Of course a lower factor can be used, in the engineer's

judgment, if he uses butt joints and is careful about the manufacture of the plate and inspection, tensile strength, and all that. He might raise the figure of 14,000 higher if he is satisfied with a lower factor of safety.

Mr. George I. Rockwood.—Boiler makers in America, I think, have fallen into the way of not using any authoritative rules of a general nature in designing steam boilers, but rather they apply the rule of common sense and arithmetic to each individual case. So that I think the paper would have less interest for us than would be the case were we Englishmen, Frenchmen, or Germans. No doubt the Navy uses the Navy rule, but certainly designers of land boilers do not use it.

Nevertheless, it seems reasonable that we should have some authoritative expression on the subject, especially with reference to the proper factor of safety for each part of a vessel, of whatever shape, built to contain high-pressure steam. I agree emphatically with the author that a committee to investigate and report upon suitable rules would be a wise one to create.

Mr. Henry I. Snell.—I would like to make a suggestion in connection with the idea just advanced, and that is, if this committee is appointed, they also be requested to formulate a rule by which the boiler shall be taken care of after we get it.

We all know that safety depends as much upon the man who has the boiler under his charge as upon the designer or builder.

I have had considerable experience in being around boilers, oftentimes in positions from which it would be difficult to escape in case an explosion occurred. I have learned that explosions occur more frequently from strong and well-made boilers than from old or weak ones. A little thought will suggest that in the one case we depend upon the strong boiler to stand any and every usage, while in the other the engineer protects his own and other lives with his care and watchfulness.

I recall a boiler which some years ago was in use on the East Boston Ferry, and had been for many years, until it had nearly all rusted out, with some of the plates so thin I have seen the engineer thrust a blade of his penknife right through them. This boiler, before and after this time, was in daily use, carrying thousands of passengers from East Boston to the city proper.

It was one of the usual type of ferryboat boilers of that period; about 10 feet in diameter and 30 feet or 40 feet long.

No serious accident ever happened to this boiler because the

engineer knew it was weak and watched it carefully ; never taxing it beyond its strength ; never taking any chances about his water.

In Philadelphia there are over 10,000 boilers in daily use. The boiler inspection laws there are very severe, and boiler manufacturers want to put on a little extra price for goods intended for this market. Since the boiler explosion at Wilt & Sons planing mill, on Front Street, Philadelphia, when four men were killed (June 27, 1879), I recall but two destructive explosions of boilers in the city of Philadelphia, where loss of life occurred, and both of these were boilers of first-class construction. One occurred at the Edison Electric Light Station, and caused much litigation ; the other at the Baldwin Locomotive Works, both resulting in a loss of life. These were what might be called strong and safe boilers, which would probably comply with all the different formulæ given in this paper, and perhaps with what new formulæ our proposed committee may formulate.

I know of many explosions in other cities, and generally they occur in strong, well-designed, but sadly neglected boilers. From these experiences, I am of the opinion that care of the boiler is as necessary a requisite for safety as strength, and that our committee, if we appoint a committee, be advised to study well Dr. Holmes' specifications of the "One Hoss Shay," and give us an admonition to have the "Deacon" always in charge of our boilers.

Mr. D. W. Robb.—I wish to second this motion which has been made, and in connection therewith I would say that I think this subject is of very great importance, well worthy of being taken up by the Society, and well worthy, if possible to obtain it, of an international commission. I think that engineers all over the world, particularly where they are interested in marine boiler work, should see the importance of this. I have had experience under the Canadian rules, which are similar to the Board of Trade rules, and while these are fairly satisfactory, there is more or less trouble because the rules are not sufficiently complete and not always consistent, and, as a matter of fact, it is not safe to undertake the construction of marine boilers without making special plans in almost every case, which have to be submitted to the local inspector, and in many cases to the department at Ottawa. This, of course, causes a great deal of delay ; material cannot be ordered, and customers are kept waiting until all the details are settled.

In regard to the general question, it seems to me that it should be, as Mr. Parsons stated, possible to formulate rules which would apply to the construction of the usual forms of boilers. But the effects produced by the destructive elements, heat, pressure, and corrosion, are very intricate, very troublesome, and very hard to protect against, and for that reason we find these variant rules and variant factors of safety. As some one a long time ago expressed it, "the factor of ignorance" is very prominent. But it seems to me that it should be possible to formulate rules which would be fairly satisfactory, and make a great saving to the customer as well as to the manufacturer, and that the factor of ignorance could be at least agreed upon.

A point which has been touched on by one gentleman here, I think, is of the very greatest importance, and perhaps the vital point of the whole thing, and that is inspection during construction. You may have your materials all right, and your rules all right, or as near right as possible, but the boiler may be entirely spoiled during construction, and I think that this question of inspection is harder to deal with and requires closer attention than any other point; it is something which perhaps can only be dealt with by the government of the country. Although it may be difficult to get the various governments, insurance companies, and other bodies to adopt anything uniform, it seems to me worth trying for, and that it is a good object for the Society. I, therefore, second the motion.

*Mr. Parsons.**—In presenting the paper, the author endeavored to lay facts before the Society, without any expression on his part either *pro* or *con*, as to the question whether it would be wise or not to appoint a committee to draft a set of rules for calculating the strength of boilers. The author makes the suggestion, if it is deemed wise to appoint a committee, that an effort be made so to form the committee that it shall contain as members representatives of the important regulations, in order that the rules as determined upon may have a universal standing. Such rules could be amended to keep pace with inventions and improvements in the same manner as they were formed.

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* Author's closure, under the Rules.